

The background features several large, overlapping, curved shapes in light green, light purple, and light blue. Scattered throughout are numerous small, yellow, triangular shapes, some pointing towards the center and others away from it, creating a dynamic, celebratory feel.

# **LQ search in eejj channel**

**Simona Rolli ( Tufts)  
blessing**



# Introduction

- This analysis is an update of the result produced in March 2003
- REMAKE data 4.11.1 up to Summer shutdown used -  $203 \text{ pb}^{-1}$
- New categories added
  - use now CC and CP electrons;
- New good run list
- New evaluation of efficiencies and background
  - fakes

# LQ production at the TeVatron

- Production

- $q\bar{q} \rightarrow LQ + LQbar$
- $g\bar{g} \rightarrow LQ + LQbar$
- $q\bar{q} \rightarrow LQ + LQbar$

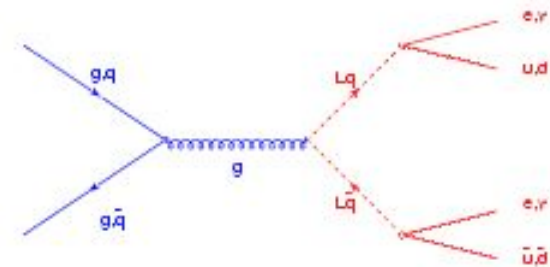
- Decay

- $LQLQ \rightarrow l^+l^-qq, l^\pm qq, qq$

$$\square = \text{Br}(LQ \rightarrow eq)$$

- Experimental signature:

- High  $p_t$  isolated leptons (and/or MET) + jets

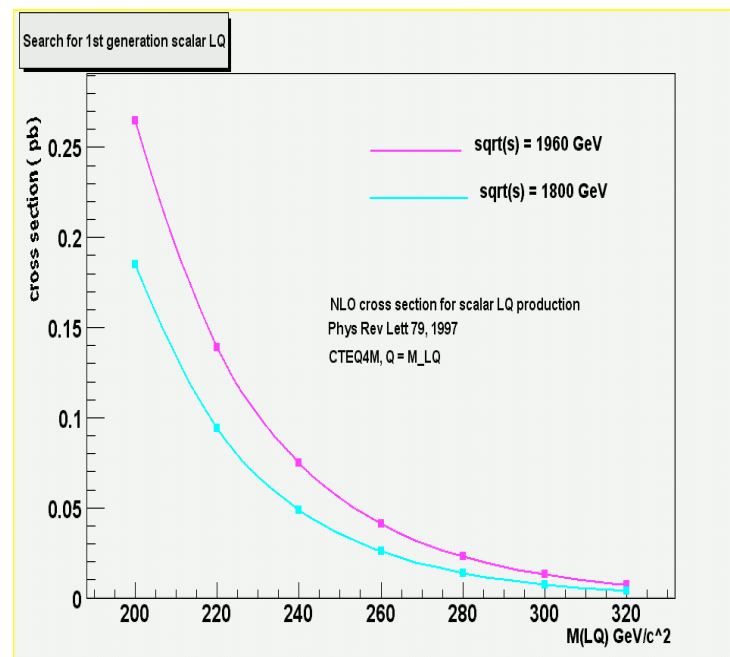


# LQ production at TeVatron

Code from Michael Kraemer (Phys.Rev.Lett 79,1997)

$s = 1960 \text{ GeV}$   
 $Q^2 = M_{LQ}^2$   
CTEQ4M pdf

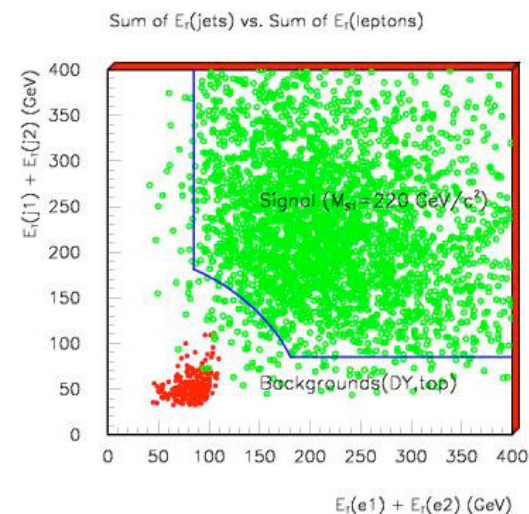
$M_{LQ} (\text{GeV}/c^2)$	$\sigma(\text{NLO}) [\text{pb}]$
200	0.265E+00
220	0.139E+00
240	0.749E-01
260	0.412E-01
280	0.229E-01
300	0.129E-01
320	0.727E-02



# LQ search in eejj

- § 2 ele with  $E_T > 25$  GeV
- § 2 jets with  $E_T(j1) > 30$  and  $E_T(j2) > 15$  GeV
- § removal of events with  $76 < M_{ee} < 110$  GeV and  $M_{ee} > 15$  GeV
- §  $E_T(j1) + E_T(j2) > 85$  GeV &&  $E_T(e1) + E_T(e2) > 85$  GeV
- §  $((E_T(j1) + E_T(j2))^2 + (E_T(e1) + E_T(e2))^2) > 200$  GeV

High  $P_T$  electron triggers (ele\_18 and Ele\_70)  
One tight electron and one loose or plug





# Tools

- Signal generated and reprocessed with 4.9.1
  - 5000 events at masses from 200 to 320
    - run number 151435
    - full beam position
      - talk GenPrimVert
      - BeamlineFromDB set false
      - sigma\_x set 0.0025
      - sigma\_y set 0.0025
      - sigma\_z set 28.0
      - pv\_central\_x set -0.064
      - pv\_central\_y set 0.310
      - pv\_central\_z set 2.5
      - pv\_slope\_dxdz set -0.00021
      - pv\_slope\_dydz set 0.00031
      - exit
- eN (4.9.1 + patches) used for ntuple analysis
  - <http://ncdf70.fnal.gov:8001/talks/eN/eN.html>



# Tools ( cont'd)

- Background MC - 4.9.1
  - DY + 2 jets
    - generated with alpgen + HERWIG
      - For cross section we used mcfm NLO
      - 50K events for  $15 < m_{ee} < 75$
      - 27.5K events for  $75 < m_{ee} < 105$
      - 50K events for  $105 < m_{ee} < 800$
  - Top
    - Pythia 5K events tt into dileptons
- Fakes from data, with isolation method and same-sign method as cross check;



# Efficiencies & acceptance

$$\epsilon_{\text{tot}} = \epsilon_{\text{Acc}}(M) \times \epsilon_{\text{D}} \times \epsilon_{\text{Z0}} \times \epsilon_{\text{trig}}$$

- Trigger
  - Top/EW - same as in  $Z'$  analysis
    - 99.9 CC
    - 96.8 CP
- Efficiencies for electron selection cuts
  - From  $Z'$  analysis
    - $\epsilon_{\text{CC}} = 92.4 \pm 0.4$
    - $\epsilon_{\text{CP}} = 79.2 \pm 0.4$
- Others
  - efficiency on the vertex cut:  $95.1 \pm 0.1$  (stat)  $\pm 0.5$  (sys)

# Kinematical and geometrical acceptance

- Events are selected where the HEPG electron is matched in a  $\Delta R = (\Delta\eta^2 - \Delta\phi^2)$  cone to the reconstructed electron ;
  - Events are further selected if falling in one of 3 categories ( geometrical acceptance -  $\Delta^{fid}$  ):
    - events with 2 central electrons ( fidele == 1 )
    - events with 2 central-plug electrons (  $1 < |\Delta\eta| < 3$  )
    - events with 2 plug-plug electrons (  $1 < |\Delta\eta| < 3$  ) -- tiny
  - Weights are derived for the 3 contributions ;
- The kinematical cuts are applied and the resulting efficiency weighted according to the CC or CP population.

# Electron ID ( Z' analysis )

- Central electron ( loose or tight )
  - $E_t \geq 25$  GeV
  - $p_t > 15$  GeV
  - $\text{hadem} \leq 0.055 + 0.00045 * E$
  - $E/p < 4$  ( for  $E_T > 100$  GeV)
  - $\text{iso4e/emet} < 0.1$  ( 0.2 for second central loose)
  - $|\text{IDeltaX}| < 3.0$
  - $|\text{DeltaZ}| < 5.0$  cm
  - Fiducial = 1
  - $\text{ls}hr < 0.2$

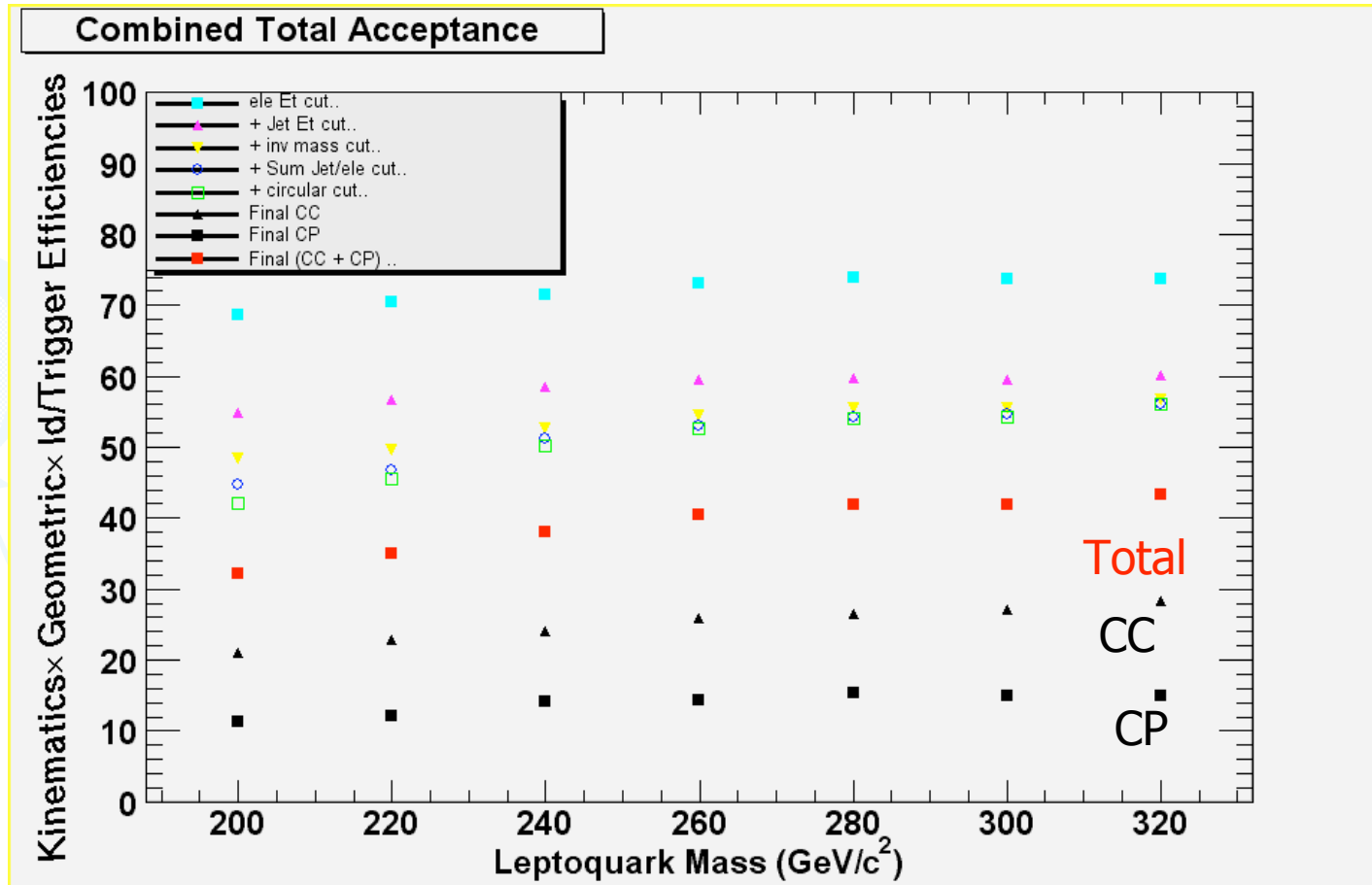
$$\epsilon_{\text{CC}} = 92.4 \pm 0.4\%$$

$$\epsilon_{\text{CP}} = 79.2 \pm 0.4\%$$

## Second Loose Plug electron

- $E_t \geq 25$  GeV
- Isolation  $< 0.1$
- $\text{hadem} \leq 0.055 + 0.00045 * E$
- $\chi^2_{3 \times 3} < 10$
- Fiducial  $1 < |\eta| < 3$

# Total acceptance





# Background expectations

tt with both W  $\rightarrow e\bar{\nu}$

pythia

$0.35 \pm 0.03$  events

DY + 2 jets

alpgen+PS/mcfn

$1.89 \pm 0.44$  events

Fakes

Isolation

$4.0 \pm 2.0$  CP

$0.0^{+0.7}_{-0}$  CC

Total

$6.24^{+3.1}_{-2.5}$



3/31/04

Simona Rolli Exotic meeting

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# Isolation method

- The isolation method relies on the assumption that since jets are produced in association with other particles, the isolation fraction of a jet will be generally larger than the corresponding one of an electron. The phase space corresponding to the 2 electrons isolation fractions is divided in 4 regions:
  - For central-central :
    - Region A )  $\text{Iso}_1^{\text{central}} < 0.1$ ,  $\text{Iso}_2^{\text{central}} < 0.2$ ;
    - Region B )  $\text{Iso}_1^{\text{central}} < 0.1$ ,  $0.2 < \text{Iso}_2^{\text{central}} < 0.4$ ;
    - Region C )  $0.2 < \text{Iso}_1^{\text{central}} < 0.4$ ,  $\text{Iso}_2^{\text{central}} < 0.2$ ;
    - Region D )  $0.2 < \text{Iso}_1^{\text{central}} < 0.4$ ,  $0.2 < \text{Iso}_2^{\text{central}} < 0.4$ ;
  - For central-plug:
    - Region A )  $\text{Iso}_1^{\text{central}} < 0.1$ ,  $\text{Iso}_2^{\text{plug}} < 0.1$ ;
    - Region B )  $\text{Iso}_1^{\text{central}} < 0.1$ ,  $0.2 < \text{Iso}_2^{\text{plug}} < 0.4$ ;
    - Region C )  $0.2 < \text{Iso}_1^{\text{central}} < 0.4$ ,  $\text{Iso}_2^{\text{plug}} < 0.1$ ;
    - Region D )  $0.2 < \text{Iso}_1^{\text{central}} < 0.4$ ,  $0.2 < \text{Iso}_2^{\text{plug}} < 0.4$ ;
- 
- 



# Isolation method (cont'd)

- We used 2 samples:
  - lepton  $P_T$  cut at 25 GeV
  - relaxed cut at  $P_T > 20$  GeV ( to let in more events)
- Extrapolating the contributions from the lower  $P_T$  cut region we estimate in the  $P_T > 25$  sample
  - 0 events in the CC region ( also 0 s.s. events)
  - $4 \pm 2$  events of background in the CP region
    - A 2
    - B 0.66
    - C 0.66
    - D 0.106
  - Although we don't make use of tracking info for plug electron - even if using DefTrack - we still find one same sign event (  $\square^{ele} = 1.1$  )



# Data sample

- btop0g (inclusive electrons) stripped from bhe108 and (4.8.4 Production)
- Inclusive-ele\_4.11.1\_REMAKE
- events selected from Ele\_18 && Ele\_70 triggers
- good runs from March 2002 to September 2003 (141544 - 168889)
  - Good run list from DQM page, em\_noSi version 4
    - Removed 4 runs due to CSL problem
    - Luminosity =  $199.7 * 1.019 = 203.5 \pm 12.2$
    - <http://www-cdf.fnal.gov/internal/dqm/goodrun/v4/goodv4.html>

# Data sample

```
module clone  Prereq HPTE
module enable Prereq-HPTE
module talk   Prereq-HPTE
L1Accept      set true
L2Accept      set true
L3Accept      set false
L3TriggerNames set ELECTRON70_L2_JET \
                    ELECTRON_CENTRAL_18 \
                    ELECTRON_CENTRAL_18_NO_L2 \
                    W_NOTRACK \
                    W_NOTRACK_NO_L2 \
                    Z_NOTRACK
debug         set false
exit
exit
```

```
module clone  StripSingleE HPE2
module enable StripSingleE-HPE2
module talk   StripSingleE-HPE2
elePtMin set 15.0
etCalMin set 70.0
delXMin set 3.0
delZMin set 5.0
show
exit
```

```
module clone  StripSingleE HPE1
module enable StripSingleE-HPE1
module talk   StripSingleE-HPE1
elePtMin set 9.0
etCalMin set 18.0
delXMin set 3.0
delZMin set 5.0
EoPMax set 4.0
lshrMax set 0.3
hademMax set 0.125
show
```

# Z cross section check

- Z boson candidates selected by requiring:  
 $70 \text{ GeV} < M_{ee} < 110 \text{ GeV}/c^2$

- Cross section is calculated as:

$$\sigma \cdot \text{Br} (pp \rightarrow Z \rightarrow e^+e^-) = (N_Z - N_{BG}) / (A_Z \cdot \epsilon_{ID} \cdot \epsilon_{trig} \cdot \epsilon_{z0} \cdot \mathcal{L})$$

	Central-Central	Central-Plug
Acceptance	$10.1 \pm 0.1\%$	$18.3 \pm 0.7\%$
ID efficiency	$92.4 \pm 0.4\%$	$79.2 \pm 0.4\%$
Trigger Efficiency	$99.9 \pm 0.1\%$	$96.8 \pm 0.1\%$
$z_0$ efficiency	$95.2 \pm 0.5\%$	$95.2 \pm 0.5\%$
Observed number of events	4568	6954
Estimated background	91.6	194.4
Integrated Luminosity	$203.3. \pm 12.2$	
Z boson cross section	$247 \pm 15.5$	$248 \pm 15.8$

Theory 250 pb



# Z + 2 jets cross section check

Events selected in the mass region 66-116 GeV  
After the 2 jets cut

Acceptances calculated from the Alpgen MC  
kinemtical and fiducial only  
ID/trigger/vertex from data

138 events after the 2 jets cut

107 in the Z mass window

Predicted:  
 $111.3 \pm 15$



# Analysis results

4 events survive the analysis cuts:

Number of events with 2 electrons with $E_T > 25$ GeV	12461
2 jets with $E_T(j1) > 30$ GeV and $E_T(j1) > 15$ GeV	138
removal of events with $76 < M_{ee} < 110$ GeV	46
$E_T(j1) + E_T(j2) > 85$ GeV && $E_T(e1) + E_T(e2) > 85$ GeV	21
$((E_T(j1) + E_T(j2))^2 + (E_T(e1) + E_T(e2))^2) > 200$ GeV	4

# A look at the events - inv masses

161633/4017143

$$j1-l1 = 319.12 \text{ GeV}/c^2$$

$$j2-l2 = 119.22 \text{ GeV}/c^2$$

$$j1-l2 = 251.0 \text{ GeV}/c^2$$

$$j2-l1 = 116.8 \text{ GeV}/c^2$$

$$M(ee) = 130 \text{ GeV}/c^2$$

156455/410939

$$j1-l1 = 519 \text{ GeV}/c^2$$

$$j2-l2 = 71.98 \text{ GeV}/c^2$$

$$j1-l2 = 342.525 \text{ GeV}/c^2$$

$$j2-l1 = 147.92 \text{ GeV}/c^2$$

$$M(ee) = 141.7 \text{ GeV}/c^2$$

167866/443088

$$j1-l1 = 219.2 \text{ GeV}/c^2$$

$$j2-l2 = 96.4 \text{ GeV}/c^2$$

$$j1-l2 = 78.4 \text{ GeV}/c^2$$

$$j2-l1 = 90.3 \text{ GeV}/c^2$$

$$M(ee) = 254 \text{ GeV}/c^2$$

162986/3598649

$$j1-l1 = 299.3 \text{ GeV}/c^2$$

$$j2-l2 = 105.7 \text{ GeV}/c^2$$

$$j1-l2 = 115.2 \text{ GeV}/c^2$$

$$j2-l1 = 192.9 \text{ GeV}/c^2$$

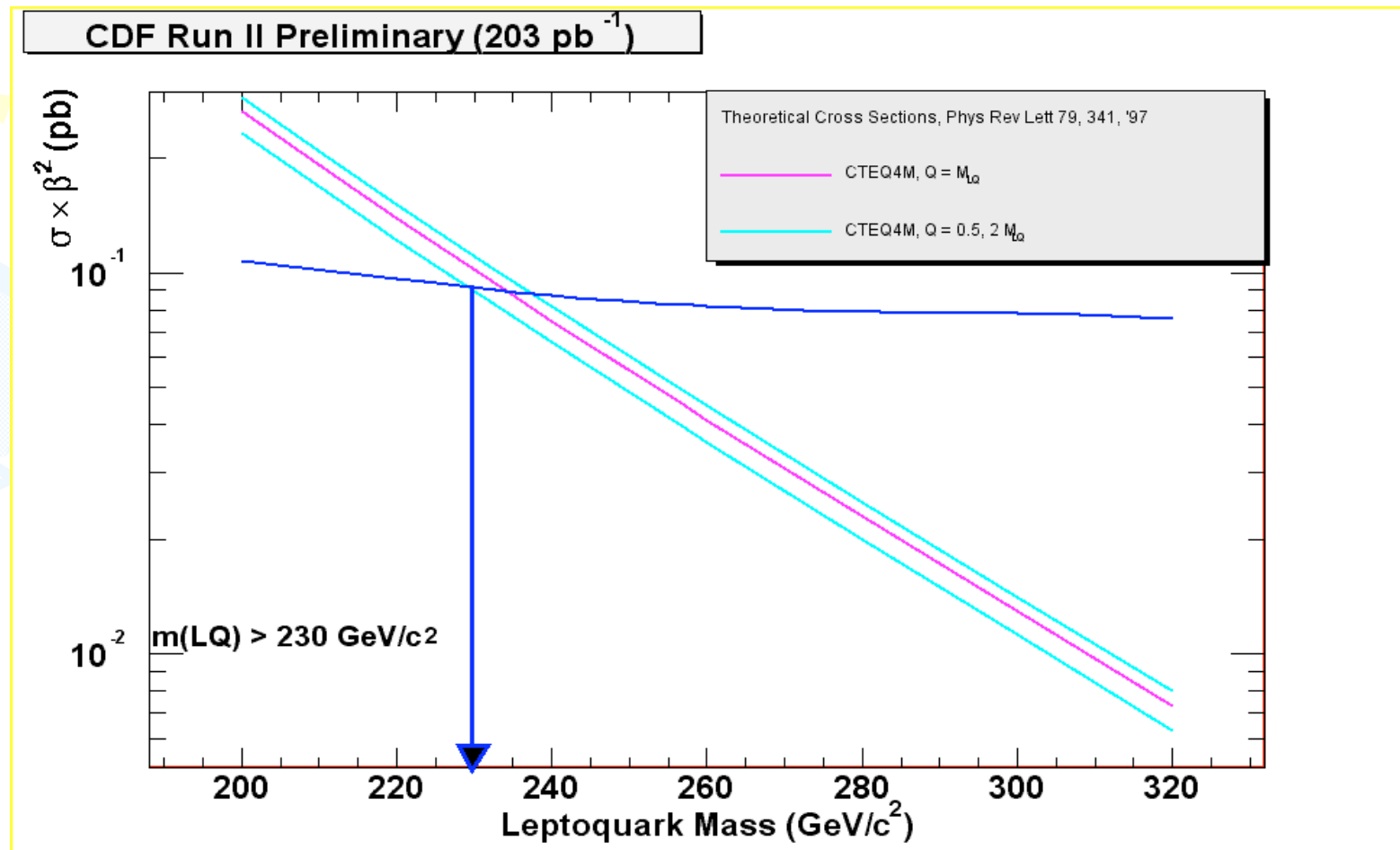
$$M(ee) = 59.7 \text{ S.S.}$$

# Systematics and combined relative uncertainty

- Luminosity.....6%
- Acceptance
  - pdf ..... 4.3%
  - statistical error of MC..... 2.2%
  - jet energy scale ...7.6 -1.3 %
- Electron ID efficiency (Z') ...0.8%
- Event vertex cut .....5%

LQ mass	Acceptance (%)	Abs Stat	Abs Sys	Tot Relative
200	32.24	$\pm 0.85$	$\pm 4.57$	0.14
220	35.07	$\pm 0.79$	$\pm 4.13$	0.12
240	38.11	$\pm 0.80$	$\pm 3.8$	0.10
260	40.4	$\pm 0.82$	$\pm 3.7$	0.09
280	41.8	$\pm 0.84$	$\pm 3.6$	0.087
300	41.9	$\pm 0.84$	$\pm 3.5$	0.084
320	43.3	$\pm 0.84$	$\pm 3.4$	0.080

# Cross section Limit





# Conclusions

- A preliminary 95% CL cross section lower limit as a function of  $M_{LQ}$ , for leptoquarks decaying with 100% branching ratio into eq ( $\epsilon = 1.0$ ) has been set.
  - CC and CP electrons have been used;
- Comparing it to the NLO theoretical predictions for leptoquark pairs production at the TeVatron, an upper limit on the Leptoquark mass is obtained at

$$m_{LQ} > 230 \text{ GeV}/c^2$$



# Difference with previous analysis

- The result presented in this note does not improve the previous result presented in March 2003.
- Signal efficiencies were overestimated due to a typo in the definition of the CC category
  - Basically the sum of all the contributions was used instead of only CC.
- Since we were looking at data in the CC region only (and observed 0 events) the cross section limit was consequently overestimated.
  - Using CC only acceptances in fact would have given a mass limit of order 205 GeV/c<sup>2</sup>.
  - On the other hand we checked that, given the good run list used in March 2003, we would have seen 0 CP events as well.
  - This would have made the limit reach 220 GeV/c<sup>2</sup>.